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Design Considerations For A Recording Instrument To Be
Used in Conjunction With R.I.T.'s Radio Astronomy System

by

Robert D. Harned

A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of Bachelor of Science in the
School of Photographic Arts and Sciences, College of Graphic
Arts and Photography, Rochester Institute of Technology

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Thesis Advisor: Dr. G. W. Schumann

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1. Information Capacity of Recording Systems

ABSTRACT

Recording of radio emission from the sun can adequately be accomplished using a magnetic tape system. Magnetic tape's advantages over other recording systems include higher information capacity, low cost, and ease of operation.

Modifications of the tape deck include the recording motor speed controlled by a SCR circuit, a suitable filtering device for the SCR, and an external fan for cooling the circuit and motor.

Careful consideration has been given to the frequency response and signal-to-noise ratio as it affects the accuracy of the recording.

INTRODUCTION

Observations of radio emissions from the sun provides additional means of examining solar radiation. Prior to the 1940's all knowledge of the sun came from optical observations which provided basic information about the sun such as structure, composition, physical conditions, on which radio studies could be built. Existence of important non-thermal processes has been revealed by the solar radio spectrum. The amount of emitted energy is on the order of 10^4 times greater than the optical spectrum. This and other properties has shown the radio spectrum to be considered unrelated to the optical spectrum. The radio emissions cover wavelengths from a few millimeters to 50 meters and is limited only by the Earth's atmosphere. The radio receiver RIT has operates on a 136 MHz carrier frequency. Thus the receiving equipment has been adjusted to receive only the 2.2 metre wavelengths emitted from the sun. By a process called detection, the receiver can change the radio frequency signal to an audio signal. The sun being a black body is a continuous emitter of all wavelengths. The antenna receives most of these but the receiver is adjusted to accept a band of only 132-140 MHz. The receiver converts this $136 \pm$ MHz signal to an equivalent, in amplitude, audio response. The audio response is presently heard in the range 16-15,000 Hz which is the frequency of the human ear. This 16-15,000 Hz is now also the receiving range, in that the signal being listened to is $136 \pm 7,500$ Hz.

BACKGROUND

When recording radio emissions at one particular wavelength as RIT's system does, there are three influential factors:

1) A constant background noise due to thermal radiation from the quiet solar atmosphere--in reality this does vary due to the eleven year solar cycle, but this may be considered insignificant.

2) A slow varying component from the centers of activity around the sunspots--related to the periods (1 week to months) of sunspots and solar rotation (27 days).

3) A highly variable component commonly referred to as bursts. The bursts last anywhere from seconds to a few hours and are related to flares and other eruptive phenomena in the sun's atmosphere.

The objective of R.I.T.'s system is to record these bursts from the non-thermal processes of emission and of this project to develop a recording instrument.

There is a definite relationship between the emitted wavelength and the temperature of the emitter. The longer the wavelength, the higher the temperature. Typically, at one centimeter the temperature is 10^4 K., while at a meter wavelength the temperature rises to 10^6 K. Also, as probably obvious from the term flare (to be explained later),

the bursts are a much higher temperature than the quiet sun.

From previous research it is known that the short (centimetre) wavelengths originate almost entirely in the atmosphere and the metre wavelengths from the tenuous corona. As expected from the chromosphere, most of the noise is the quiet sun and the slowly varying components. Bursts are very rare in this short wavelength region. Around the metre wavelength the quiet noise is very feeble, the slowly varying component almost non-existent, while the bursts are dominant when there is eruptive activity.

There is a definite relationship between radio bursts and solar flares. Bursts may be characterized as either: 1) electrongyro radiation, 2) synchrontron radiation, or 3) plasma radiation. All these different types of bursts occur either at the time of flares, are started by flares, or occur in flare producing regions. The greatest intensities of bursts occur at the metre wavelengths lasting seconds or a few minutes. At the shorter wavelengths bursts are infrequent and when they do occur last from a minute to an hour. Continual bursts lasting for a period of days is called a storm. Storms usually follow flares and are emitted from the flare region. Storms occur mostly in the metre wavelength range.

Flares are divided into two groups: 1) small flares, and 2) large flares, each having its own radio emission characteristics. Small flare events are identified by their

occurring in groups lasting about one minute with each burst lasting about ten seconds. Also there are metre wavelength bursts coincident with centimetre ones. Here the metre wavelength bursts are sharper when compared to the smaller wavelengths. An examination of the radio spectrum during these bursts reveals that the bursts start out at a high frequency and gradually tapers off to lower frequencies but the lower it falls the longer it stays on that frequency.

Large flare events have two distinct phases in the radio spectrum. The first phase is similar to that described for small flares. After the quiet period of several minutes the second phase starts. Here bursts occur only in the metre wavelength region lasting 5-30 minutes. The frequency again drops with the time but here on the order of two-hundred times slower.

INSTRUMENTATION

The recording of the signal from the sun is done using a magnetic tape system. Magnetic tape was chosen over a photo-optical and pen-chart systems because of its far superior information capacity, low cost, and ease of operation. Table 1 shows a comparison of the information capacity of the various systems for a one dollar operational cost over a ten hour recording period. These operational specifications were proposed by the physics department at R.I.T. for whom the tape recorder is being converted. For the one dollar 1200 feet of magnetic tape can be purchased. Consequently the recording speed had to be adjusted to 36 inches per minute in order to use just the 1200 feet during the ten hours.

At this recording speed the information capacity is 5250 bits/sec. and has a frequency response of 100 to 2800 Hz \pm 1db. This frequency range will now set the band width of the receiver as the human ear did as discussed previously. The bandwidth is now 136 mHz \pm 1450 Hz. The maximum frequency range the tape can record without distortion will be used, as opposed to a narrower bandwidth, because the larger range will have a correspondingly larger signal to the recorder in terms of input voltage. Thus it will be easier to differentiate any change in amplitude of the signal.

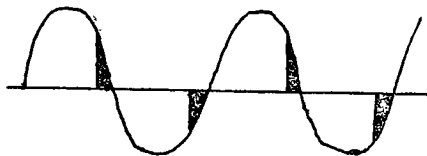
Originally the capstan on the tape recorder was to be

replaced with one about .3 times its diameter to reduce the speed to 15.2 mm/sec. When no substitute could be found it was thought that the original capstan could be milled down to the proper size. This could not be done however, because the diameter of the capstan was only $3/16$ inch and any grinding would have broken it. In addition the pause roller assembly could not have been easily adjusted to fit the new diameter of the capstan.

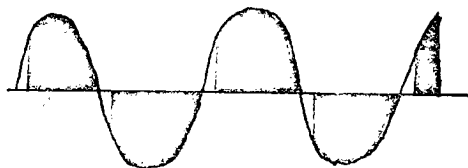
After considering both a variable resistor and a silicon controlled rectifier (SCR) motor speed control, it was decided to use the SCR. The SCR was chosen because there would be no loss in torque as the voltage remains constant during operation. The variable resistor would decrease the voltage across the motor thus decreasing the torque. An additional advantage of the SCR is that the speed of the recorder will be variable, not set at any one speed as with the mechanical modification described. Therefore, if for some reason the recorder is needed to operate at a faster speed or an even lower speed this may be done. Reasons for operating at a higher speed might include an increase in frequency response so there would be a larger recording range resulting in a stronger output signal to and from the recorder, or a higher playback speed to find bursts quickly. If for any reason recording over longer periods of time than ten hours continuously is desired, the variable speed will allow that.

The SCR circuit has been inserted so that it will control

only the voltage to the motor and not affect the voltage to the recording circuits. The circuit for the SCR is shown in Figure 1. Essentially, the SCR speed control switches the power on and off very rapidly thus providing power only at momentary intervals. Normally a SCR only turns on during either the positive (or negative) half-cycles which provides the pulsating current. The circuit used here incorporates two SCR's (called a quadrac) so that both the positive and negative portion of the wave can be chopped simultaneously. The potentiometer can be adjusted so that the "triggers" are applied to the gates anywhere between the positive and the negative half-cycles. For example, when the potentiometer is set for a low resistance the SCR's are triggered on only for a short duration as in Figure 3 .



If the potentiometer is set near the maximum the trigger point will be changed and the SCR's will be on for a longer duration as in Figure 4 .



The instantaneous speed variation due to the motor being switched on and off will be negligible because of the flywheel

connected to the capstan in the tape deck.

Several problems were anticipated with the SCR circuit. The first is the possibility of the overheating of the quadrac and the motor. The quadrac used has a built-in heat sink which is sufficient to dissipate the heat. An additional electric fan has been placed in the recorder to cool the motor and has so far proved adequate.

The second problem is that the quadrac causes radio frequency interference which will disturb the time signal record to be discussed later. This RF interference has been eliminated by using a noise suppressor connected in series to the live wire from the wall and will filter off the interference.

EXPERIMENTAL PROCEDURES

Once modified, the tape deck was tested to determine its frequency response and signal to noise ratio. The frequency response was used to set the bandwidth of the receiver. If signals of higher (or lower) frequency than what the recorder could accept without distortion were recorded, the amplitude of the tape will be distorted and would not accurately reflect the sun's changing signal. The signal to noise ratio is the maximum signal amplitude obtainable from the tape recorder before distortion sets in, compared to the noise inherent in the system.

The frequency response was determined as follows:

- 1) recording the signal from a constant amplitude audio oscillator over a frequency range of 50-15,000 Hz, 2) playing the tape back through an A.C. voltmeter calibrated to read decibels, and 3) plotting frequency versus decibels. The results as shown in Figure 2 indicate that the frequency response of the recorder operating at 40 in./sec. is 10 to 2,800 \pm 1 db.

Indetermining the signal to noise ratio a 400 Hz signal was fed into the recorder and the sinusoidal output viewed simultaneously on an oscilloscope. Using the volume switch on the recorder, the amplitude of the signal was increased until there subjectively appeared to be a 3% distortion. The

amplitude at the 3% distortion point was measured on the A.C. voltmeter. The meter reading was $42 \pm .5$ db. This amplitude was the maximum signal before any significant distortion set in. The noise in the system was expected to come from the preamplifier only and not the blank tape. With a blank tape being played the voltmeter did not move indicating the noise is not significant compared to the measuring device for the signal. The inherent noise, if present, is not significant as what is to be measured when recording the sun's activity, is a relative change from the constant background noise.

The signal-strength meter, commonly referred to as the V.U. meter, on the recorder indicates whether the signal amplitude is such that there will be distortion. When recording the needle should not go into the distortion range marked. The minimum distortion line on the V.U. meter has been calibrated to 42 db signal found to be the maximum signal for distortion.

The output recorded on a pen-chart recorder can, if desired, separate the various components of the recorded intensity, by selective recording. To differentiate the quiet sun and the slowly varying component the intensity must be recorded over a period of time. If a daily plot of intensity versus sunspot area is kept, the intensity when there are no sunspots (zero area) is the quiet sun. The difference between the recorded intensity and the quiet

noise is the slowly varying component. Bursts may be differentiated by comparing the signal during a solar flare to the first two components discussed above.

RADIO RECORDING

When recording the signal from the sun a time record is important. This is recorded on the second channel using a short-wave receiver tuned to WWV (either 5, 10, 20, or 25 kHz) which gives the time every minute. Although the frequency response is only to 2,800 Hz, it should be adequate for this vocal application.

To find the bursts, once the signal is recorded, the tape deck can be set on fast-forward and the output viewed on an A.C. voltmeter. The needle should remain fairly steady until a burst, where it will jump. Using this procedure, a ten hour tape can be reviewed in a manner of minutes and if no burst present, erased and reused. If bursts are present, the tape can be played back slowly through the burst period and graphically displayed using a pen-chart system connected to the deck output.

RESULTS

Modification of the tape deck for operation in the 15 to 120 in/min. speed range was successfully completed. The frequency response was 100 to 2,800 Hz \pm 1 db as graphically shown in Figure 2, while the signal to noise ratio was not calculable as no noise could be measured. These values were determined for the head originally on the recorder. It has since been replaced, because it did not erase properly, but both the frequency response and signal to noise ratio data is expected to be approximately the same.

Actual recording of the signal from the sun has not yet been done because of a defective erase head and damage done to the recorder by a fire. While trying to determine why the erase head was inoperative, the recording circuit was inadvertently overloaded causing two transistors and a resistor to overheat. The heat from these ignited the lacquer on the circuit board. The damage was confined to just the components mentioned.

The tape deck has since spent the last seven weeks at University Electronics of Rochester being "repaired". At present everything is operating correctly except for the cord from the head to the amplifier and bias oscillator. The cord, according to the serviceman, has a "leak" in it and must be replaced. It has been on order for quite some time and it is expected shortly. Until it is replaced the recorder cannot record, erase, or playback.

CONCLUSIONS

Recording of radio emission from the sun can be done using a magnetic tape system and a radio-astronomy receiver similar to R.I.T.'s. Magnetic tape has a low cost and high information capacity as compared to a photo-optical or pen-chart system. Also, if the tape is played back through a speaker during a suspected burst period, extraneous noise can be identified which is not possible with either of the other systems. By reducing the recording speed, cost can be minimized. For R.I.T.'s purposes the recording speed was reduced to 36 in/min. to keep the cost at less than one dollar per ten hour period. The speed is controlled by an SCR circuit which gives a higher torque at a lower speed. The SCR's ability to vary the speed over a 15 in/min. to the normal 120 in/min. range is a distinct advantage over any mechanical means which limits recording to one speed.

The frequency response varies with speed and must be measured for each speed. On the tape deck used here the signal to noise ratio was not calculable, as with the testing equipment used no noise could be detected.

RECOMMENDATIONS

Although at the lower speeds the motor operates satisfactorily, the recorders effectiveness could be increased by replacing the existing motor with one having a higher torque. Presently at speeds under the 30-35 in/min. range the motor appears to "labor" and there is a cut-off point at 15 in/sec. below which the motor will not operate.

Figure 2

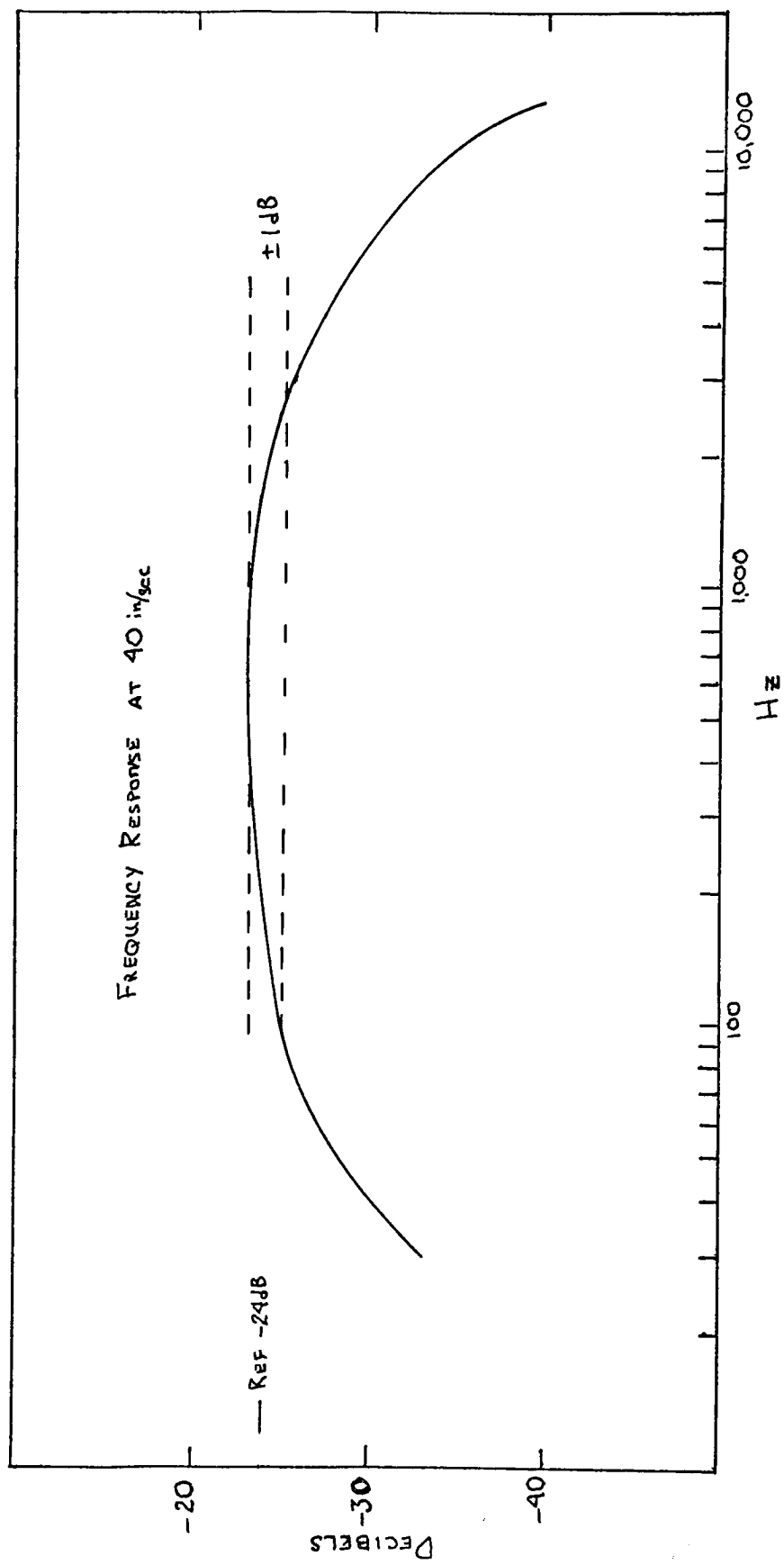


TABLE 1

<u>System</u>	<u>Max. Cells</u> <u>mm.</u>	<u>Max. Levels</u>	<u>Max. Inf.</u> <u>Capacity</u>
Magnetic Tape	525	1000	5250 bits/mm.
Pen-Chart	1	250	8 bits/mm.
Kodak fine Grain	0.44	4	.88 bits/mm.

Information capacity calculated from:

$$I = \log_2(\text{Levels})^{\text{cells}}$$

LIST OF REFERENCES

- Radio Astronomy Ed. by J.B.Evens and Tor Hghors, McGraw Hill Book Company, N.Y. 1968.
- Paris Symposium on Radio Astronomy, Ed. by Ronald Bracewell, Standford University Press, 1959.
- Radio Astronomy, J.A. Clegg and B. Lovell, Chapman and Hall Ltd., London, 1952.
- Radio Astronomy, H.C. van de Hulst, University Press, Cambridge, 1957.
- Radio Astronomy and How to Build your own Telescope, J. Heywood, Ark Books Inc., N.Y. 1963.
- Radio Astronomy, J.D. Kraus, McGraw Hill, N.Y. 1968.
- Radio Astronomy, Mukel Kundu, Interscience Publisher, N.Y. 1965.
- Radio Astronomy, J.L. Steinberg, McGraw Hill, N.Y. 1963.
- Radio Astronomy Today, Ed. by H.P. Palmer, Harvard University Press, Cambridge, 1963.
- Radio Exploration of the Sun, A.G. Smith, D. Van Nostrand Company, Princeton, 1967.
- Tape Recorders and How They Work, C.G. Westcott and R.F. Dubbe, The Bobbs-Merrill C?ompany, N.Y., 1964.
- The Radio Amateurs Handbook, Editor D. DeMaw, American Radio Relay League, Inc., 1971.
- Sams Photofact V. TR-69, H.W. Sams Engineering Staff, Howard W. Sams and Co., Indianapolis, 1970.
- RCA Silicon Controlled Rectifier Experimenter's Manual, Radio Corporation of America, Harrison, N.J., 1967.
- Fundamentals of Photographic Theory, T.H. Janes, G.C. Higgins, Morgan and Morgan, N.Y., 1968.